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Original Research

Humeral Condylar Fractures in French Bulldogs: Prevalence of Contralateral Intracondylar Fissure, Treatment, and Outcome

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Abstract

Objective The aim of this study was to report (1) the prevalence of contralateral humeral intracondylar fissure (HIF) in French Bulldogs with humeral condylar fractures (HCF) and (2) treatment and short- and long-term outcome in French Bulldogs with HCF.

Materials and Methods Medical records of French Bulldogs treated surgically for HCF between January 2011 and November 2022 were reviewed. Perioperative imaging, surgical technique, complications, and long-term outcome were assessed.

Results Eighty-nine dogs with HCF were included and 36/89 were diagnosed with HIF. Surgical repair was performed in all HCF and a prophylactic transcondylar screw was placed in 20/36 HIF. For prophylactic transcondylar screw placement, two dogs required immediate revision surgery. Complications occurred in 12/89 HCF, and there were major complications in 6/89 HCF. Long-term outcome evaluated by owner questionnaire ($n = 27$) was rated as being excellent in 18/27 dogs, good in 8/27 dogs, and fair in 1/27 dogs.

Clinical Significance Forty percent of French Bulldogs with HCF had a contralateral HIF. HIF as a cause of HCF should be considered in the French Bulldog, and a computed tomography (CT) scan of both elbows may be advisable prior to HCF repair. The complication rate of HCF surgery in the French Bulldog is significant.

Keywords
- elbow
- incomplete ossification
- French Bulldog
- lameness
- stress fracture

Introduction

French Bulldogs are reported to have a higher rate of humeral condylar fractures (HCF) than other breeds, but the reasons behind this are unclear.[1,2] Spaniel breeds are also known to have a high prevalence of HCF with humeral intracondylar fissure (HIF) being a causative factor.[3–6] Three studies have found evidence of HIF in the contralateral elbow of French Bulldogs with HCF in 6 of 9, 6 of 41, and 18 of 31 dogs.[7–9]

Two theories have been proposed to explain HIF. The first was incomplete ossification of the humeral condyle,[3] as the area of radiolucency is in the same anatomical area as the union of the medial and lateral ossification centers. Although ossification of the canine humeral condyle has been reported to be complete by 6 weeks,[10] it is unclear from which data this was obtained. The second theory is a stress fracture.[3,6,11,12] In one study, a Cocker Spaniel with a

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previously intact left humerus developed an HIF, followed by an HCF. The spontaneous development of the HIF was confirmed by two computed tomography (CT) scans performed nearly 2 years apart.[6] Presence of sclerotic bone adjacent to the fissure also supports the stress fracture theory,[12] and biopsies taken from HCF have confirmed the absence of cartilage with the presence of sclerosis suggesting chronic inflammation.[3,11] It is for these reasons that the term HIF is preferred and will be used in this study.

Humeral intracondylar fissure can be diagnosed with radiographs, but CT scan has a higher sensitivity.[13]

Humeral condylar fractures can happen at any age, with a peak incidence at 4 months.[1,7,9] Complication rates of HCF repair vary from 13.3 to 40.9%,[2,9,14–17] and clinical outcomes have been reported as excellent in 49.6 to 87%.[2,7,15,18,19] For transcondylar screw placement for HIF treatment, complications range from 15 to 69%.[17,20–23]

The purpose of this study was to determine the prevalence of contralateral HIF in French Bulldogs with HCF. In addition, the study aimed to evaluate the prevalence of complications, short- and long-term outcomes, and the relationships between outcome, fracture configuration, and implants used.

Materials and Methods

Data Collection

Medical records of French Bulldogs presented at two hospitals (Vets Now Referrals Glasgow and Andrew Miller & Associates, Stirling) from 2011 to 2022, with HCF treated surgically, were reviewed. The inclusion criteria were the following: French Bulldogs, with HCF repaired surgically, that underwent concurrent radiographic or CT imaging of the contralateral elbow. Data recorded included age, weight, sex, neuter status, surgically treated limb, type of HCF, nature of the incident, previous history of lameness, preoperative and postoperative imaging, implants placed, complications encountered, and short- and long-term outcome. Trauma was classified as minor, such as a low-impact event (e.g., running, playing with another dog, jumping from a height of <1 m), moderate (e.g., jumping from a height of >1 m, toddler falling over the dog), or major (e.g., falling from >1.5 m, road traffic accidents). Time frames and complications were categorized as per current recommendations.[24] Short-term outcome was assessed at reexamination or by completion of an owner questionnaire (►**Supplementary Appendix 1**, available in the online version). Long-term outcome was assessed with the same questionnaire.

Radiographic and CT Data Collection

Preoperative orthogonal radiographic views of HCF were obtained at initial presentation. Additionally, a craniocaudal radiographic view of the contralateral elbow was performed in 78 dogs, a CT scan in 39, and both tests in 28 dogs.

All the images were assessed at the time of presentation and retrospectively by board-certified small animal surgeons. The diagnosis of HIF was made as per previous definitions.[12]

Surgical Technique

Fractures of the lateral part of the humeral condyle were stabilized through a lateral approach and fractures of the medial humeral condyle through a medial approach.[25] Comminuted T/Y fractures of the humeral condyle, with an intracondylar articular component and complete supracondylar transverse or oblique fractures, were approached using a combined medial and lateral approach.[26] Fracture repair consisted in all cases of a transcondylar screw with additional epicondylar fixation. The epicondylar method of fixation consisted of Kirschner wire(s) only, epicondylar screw (s) ± Kirschner wire(s), and plates ± epicondylar screw(s). If a complete HIF was diagnosed in the contralateral elbow at the time of surgery, placement of a prophylactic transcondylar screw was generally advised as per current recommendations[3,5,20,21] and were placed via a medial approach.[26]

Post-operative Radiographic Evaluation

Follow-up images were obtained at reexamination, between 3 and 9 weeks postoperatively. Progression of bone healing, changes of alignment, apposition or implant integrity, and any other complications were recorded.

Length of the transcondylar screws was classified as appropriate (1–4 screw threads exiting the transcortex), short (no screw threads exiting the transcortex), or long (>4 screw threads exiting the transcortex). Any gap between plates and the bone were described as small (<2 mm) and large (>2 mm).[26]

Owner Questionnaire

A questionnaire to evaluate short- and long-term outcome after HCF repair was created (►**Supplementary Appendix 1**, available in the online version). Outcome was defined as excellent, good, fair, or poor. Outcome was considered excellent if there was no reported lameness, stiffness, difficulty climbing or jumping up and down, and if no analgesic medications were used; good if there was occasional stiffness/lameness but with no restriction to activity, or if there was mild/moderate difficulty climbing or jumping up and down, or if dogs required intermittent analgesic medication; fair if there was good exercise tolerance but with frequent lameness or stiffness, and need for analgesic medication; and poor if there was constant lameness causing restriction to activity.

Statistical Analysis

A social science statistics Web site program (www.socscistatistics.com) was used to perform statistical analysis, and graphs were produced using Microsoft Excel. Descriptive statistics were performed. Associations between all categorical data were assessed using chi-squared tests. Values of $p < 0.05$ were considered significant for all tests.

Results

Eighty-nine dogs met the inclusion criteria. The median age of the dogs was 4 months (range: 3–72 months) with 76/89 being between 3 and 5 months. Eighty-three elbows were

fractured after a minor/moderate trauma and in 14 dogs no trauma was witnessed. Two dogs had a history of a prior lameness in the fractured limb. Another two had a prior contralateral lameness, and the elbow was later diagnosed with HIF. None of the dogs were lame at the time of presentation on the limbs diagnosed with HIF.

Imaging

Out of 89 elbows, 66 had a lateral, 12/89 had a medial, and 11/89 had a T/Y fracture of the humeral condyle. Contralateral imaging was obtained with radiographs only in 50 dogs, with CT scan only in 11 dogs, and both modalities were used in 28 dogs. In 36 dogs, an HIF was diagnosed on the contralateral elbow (40.44%). Of the 36 HIF, 14 were detected using radiographs only ($n = 14/50$), 3 using CT scan only ($n = 3/11$), and 19 using both imaging methods ($n = 13/28$ by radiographs and $n = 19/28$ by CT). A comparison of the appearance of an HIF in radiographs versus CT scan can be seen in ►**Fig. 1**. Twenty-eight out of 36 HIF were diagnosed at the initial presentation; in the additional 8 dogs, HIF was diagnosed retrospectively when data were collected for this article.

Surgery

Surgery was performed in all the HCF and 20 of the 36 HIF had a prophylactic transcondylar screw placed. The decision to place a prophylactic transcondylar screw, and implant selection, was dependent on the surgeon's preferences and the dog's age. Fluoroscopy was used in four dogs. Surgical repair of the epicondylar part for lateral and medial fractures in dogs younger than 6 months was performed with Kirschner wires in 31 fractures, followed by plates (9 veterinary cuttable plates [VCP], 8 locking compression plates [LCP], 1 acetabular plate, and 2 unknown), epicondylar screws in 20 dogs, and epicondylar screws with Kirschner wires in 1 dog. All the lateral and medial fractures in dogs older than 6 months were repaired using a plate for the epicondylar fragment (3 dynamic compression plates [DCP], 2 LCP, and 1 acetabular plate). For dogs younger than 6 months that suffered T/Y fractures, three were repaired with a plate on one epicondylar region, and a Kirschner wire on the other (1 LCP, 1 DCP, and 1 VCP), 1 with a VCP and a lag interfragmentary screw on one epicondyle and a VCP on the other, 1 with a VCP and a lag interfragmentary screw on one epicondyle and a lag interfragmentary screw on the other, 1 with an LCP in one epicondyle and a VCP in the other, and 1 with a Kirschner wire in both epicondyles. Dogs with T/Y fractures older than 6 months were repaired with bilateral DCP in 2 dogs, bilateral VCP in 1 dog, and a VCP in one epicondyle and an LCP in the other in 1 dog. All the dogs had additional interfragmentary lag screws. The sizes used for the transcondylar screws were 2.0 mm ($n = 2/89$), 2.7 mm ($n = 21/89$), 3.5 mm ($n = 57/89$), and 4.5 mm ($n = 9/89$). Transcondylar screws were drilled in a retrograde fashion in 20 dogs, normograde in 74 dogs, and unspecified in 3 dogs. Transcondylar screws were placed in a lag fashion in 37 dogs, positional in 49 dogs, and unspecified in 11 dogs. Prophylactic transcondylar screw sizes used were 2.7 mm ($n = 4/20$), 3.5 mm ($n = 15/20$), and 4.5 mm ($n = 1/20$).

Postoperative radiographs revealed satisfactory reduction and implant positioning in 72 of 89 HCF. Sixteen had acceptable post-op radiographs with some minor concerns: transcondylar screw too short in 5 dogs, transcondylar screw too long in 4 dogs, small gap at the epicondylar fracture line in 4 dogs, gap between the plate and the bone in 2 dogs, and both epicondylar Kirschner wire and transcondylar screw too short in 1 dog. Of the 20 HIF that had a prophylactic transcondylar screw placed, 2 had an inappropriate length (too long or too short), which were corrected under the same anesthetic.

No intraoperative complications were reported for the fracture repairs or for the prophylactic screw placement.

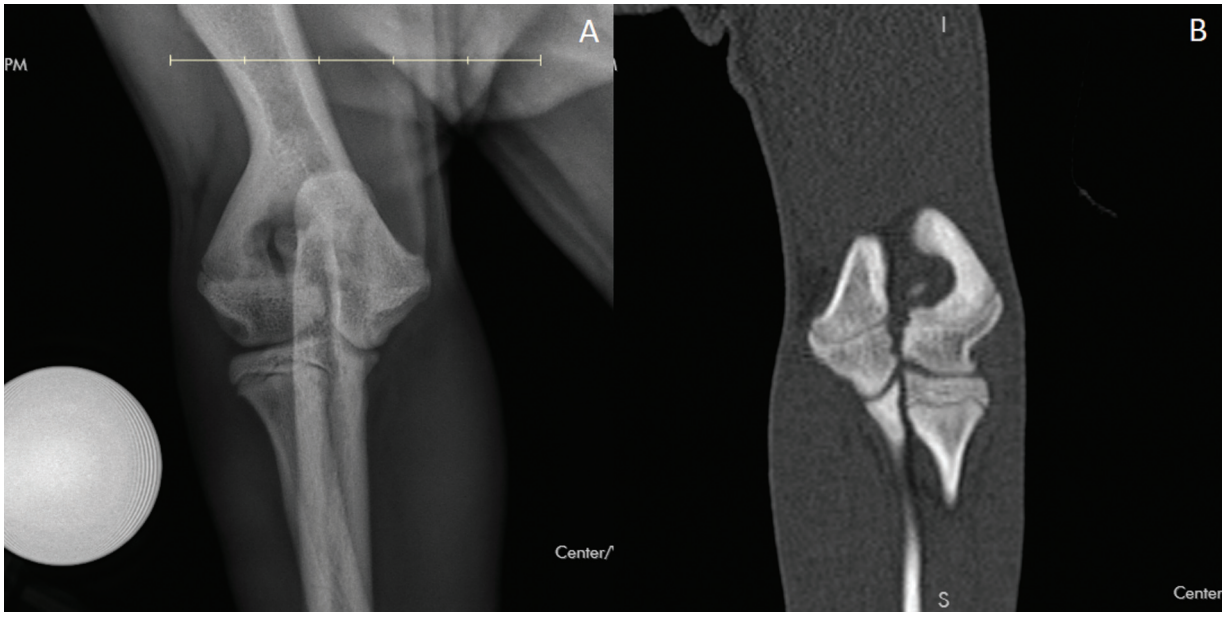

Fig. 1 Comparison of the (A) radiographic and (B) computed tomography appearance of humeral intracondylar fissure (HIF).

Table 1 Short- and long-term complications

Minor: 6/89	Major: 6/89	
	Surgical: 6/89	
	Implant removal: 4/89	Implant replacement: 2/89
Seroma ($n = 2$)	Lucency around transcondylar screw requiring removal ($n = 2$)	Implant migration (transcondylar screw and Kirschner wire), $n = 1$
Migration transcondylar screw ($n = 1$)	Lameness and pain over Kirschner wire requiring implant removal ($n = 1$)	Lameness and reduced range of motion requiring transcondylar screw replacement ($n = 1$)
Epicondylar implant failure that required no action ($n = 1$)	Implant migration (Kirschner wire) needing removal ($n = 1$)	
Radioulnar incongruence ($n = 1$)		
Increased intracondylar gap ($n = 1$)		

Short-Term Outcome

Short-term outcome information was available in 55 of 89 dogs. In 48 dogs, the information was recorded at reexamination, which was advised at 4 to 6 weeks postsurgery. In three dogs, the information was available by phone call, and in four dogs, information was extracted from the owner questionnaire.

In the cases where information was acquired by the owner questionnaire, two dogs returned to normal use of the limb within 1 month postsurgery and three dogs within 3 months postsurgery.

From the consult notes, information was extracted regarding lameness, range of motion, pain, or discomfort. Information about lameness was available in 43 dogs. Twenty-two dogs showed no lameness, and 10 dogs were described as having good limb use or walking well. Eight dogs were described as having a slight, mild, or moderate lameness. Three dogs had a marked lameness or a grade $\geq$5/10.

Range-of-motion information was available in 37 dogs. It was normal in 13 dogs, very good in 3 dogs, good in 16 dogs, and reduced in 5 dogs.

Pain or discomfort was reported in 3 dogs upon limb manipulation or implant palpation. One of these dogs had a surgical site infection with *Staphylococcus pseudintermedius* cultured, the Kirschner wire was removed, and the dog was prescribed clindamycin 11 mg/kg every 12 hours for 14 days. Another dog was markedly lame and painful upon palpation of the epicondylar ridge; the Kirschner wire was removed; arthrocentesis cytology and culture were negative. The third dog had moderate radioulnar incongruency on radiographs.

Short-term follow-up imaging (radiographs or CT scan) was available in 45 dogs between 4 and 6 weeks postsurgery. There were signs of bone healing in all the dogs, with 18 being fully healed. An intracondylar gap/HIF was still visible in 14 HCF repairs.

Short-term complications were seen in 12 HCF. Six were minor and six were major, with four requiring implant removal and two requiring implant replacement. Further details are summarized in ►**Table 1**.

Short-term follow-up for dogs with HIF treated with a prophylactic transcondylar screw was done at the same time than for HCF. Humeral intracondylar GAP/HIF was still visible in two elbows when radiographs were performed. No complications relating to prophylactic transcondylar screw placement occurred.

The prevalence of complications was assessed with respect to the type of epicondylar repair in lateral and medial HCF. Most complications occurred in the Kirschner wire group ($n = 6/10$). This was followed by the group where a screw was used for the epicondylar repair ($n = 2/10$), the group repaired with plates ($n = 2/10$), and the group repaired with screws and a Kirschner wire ($n = 0/10$; ►**Table 2**). This was not significant when a chi-squared test of independence was performed: χ^2 (DF = 2, $N = 80$) = 1.30, $p = 0.52$. When the prevalence of complications was assessed with respect to the type of epicondylar repair for T/Y fractures, all complications occurred when Kirschner wires were used (100%; ►**Table 3**). The type of fracture and the prevalence of complications were also evaluated, and the number of dogs that suffered complications did not differ by type of fracture: χ^2 (DF = 2, $N = 89$) = 2.04, $p = 0.36$ (►**Table 4**).

Long-Term Outcome

A questionnaire was completed by 27 owners (30.33%). The median duration of long-term follow-up was 20.7 months (range: 12.2–55.1 months). Long-term outcome was considered excellent in 18 dogs (66.66%), good in 8 dogs (29.62%), and fair in 1 dog (3.7%). The dog with a fair outcome was able to use the limb reasonably well but with stiffness and frequent lameness causing some restriction to activity. The owner was not administering any analgesic. In this dog with fair outcome, perfect reduction was not possible during surgery and the transcondylar screw was reported to be too short on the postoperative radiographs. Subsequently, this dog had implant failure, and revision surgery was recommended, but the client declined.

A chi-squared test of independence was performed to examine the relationship between complications and an

Table 2 Complications encountered depending on type of epicondylar fixation in unicondylar fractures

Epicondylar fixation in unicondylar fractures	Surgeries performed	Complications	Minor complications	Major complications
Kirschner wires	35	7	2	5
Screws	20	3	3	0
Plate	29	2	2	0
Screws and Kirschner wire	2	0	0	0
Total	78	10	5	5

Note: The Kirschner wire group had the most complications ($n = 6/31$). This was not significant when a chi-squared test of independence was performed: χ^2 (DF = 2, $N = 80$) = 1.30, $p = 0.52$.

Table 3 Complications encountered depending on type of epicondylar fixation in T/Y fractures

Epicondylar fixation in T/Y fractures	Surgeries performed	Complications	Minor complications	Major complications
Bilateral plates	7	0	0	0
Plate and Kirschner wire	4	2	1	1
Total	11	2	1	1

Note: All complications occurred when Kirschner wires were used.

Table 4 Complications depending on type of fracture

Type of fracture	Surgeries performed	Complications	Minor complications	Major complications
Lateral	66	7	3	4
Medial	12	3	2	1
T/Y fractures	11	2	1	1
Total	89	12	6	6

Note: The proportion of dogs that suffered complications did not differ by type of fracture; χ^2 (DF = 2, $N = 89$) = 2.04, $p = 0.36$.

excellent or good outcome. Fair and poor outcomes could not be evaluated as only one dog had a fair outcome and 0 dogs had a poor outcome. The relationship between these variables was significant: χ^2 (DF = 1, $N = 26$) = 7.04, $p = 0.007$. Dogs that did not suffer complications were more likely to have an excellent or a good outcome.

None of the untreated HIF were reported to develop a fracture, but one of the dogs (case 26) that had an unremarkable contralateral radiograph at time of diagnosis developed a medial HCF during normal activity (running in the park) 2.5 years later.

Discussion

To the authors' knowledge, this is the largest study to date showing the prevalence of HIF in the contralateral elbow of French Bulldogs with HCF. In our study, 40.44% of French Bulldogs with HCF had a contralateral HIF, which is higher than the previously reported prevalence of contralateral HIF in non-Spaniel breeds with HCF (25–33%).[9,27] French Bulldogs suffer from HIF, but whether incomplete ossification of the humeral condyle occurs (in this breed or in any other) is unknown. All the dogs in our study were older than 6 weeks (3 months–5.5 years), which is the reported timeline for radiographic fusion of the lateral and medial parts of the humeral condyle; hence, the diagnosed HIF could not be attributed to normal anatomy. Case number 26 suffered an HCF when the dog was 22 months old. The contralateral elbow was evaluated with radiographs at that time and no HIF was detected. Two and a half years later, the contralateral elbow suffered an HCF during normal exercise (running in the park). This fact is highly suggestive that French Bulldogs suffer from HIF, and this may appear later in life, similar to Spaniel breeds. In this last case, CT scan would have been the preferred diagnostic method to ensure no HIF was present at initial consultation.[6] Our study highlights the superior diagnostic quality of CT scan compared with radiographs as six HIF could only be seen on a CT scan. A 15-degree craniomedial to caudolateral oblique radiograph has been recommended to increase the probability of diagnosing HIF on radiographs.[13] However, this recommendation is difficult to execute.

In our study, the majority of HCF were lateral (74.15%), followed by medial (13.48%) and T/Y fractures (12.35%). These results differ from another study[2] where although lateral HCF were still the most common in the French Bulldogs, the percentage did not differ as much from medial HCF (48 and

29%, respectively). This last study also found that medial HCF occurred predominantly in chondrodystrophic dogs.

The complication rate in our study for fracture repair was 13.4%: 6.7% minor and 6.7% major. These percentages are similar to those of previously published studies (13.3–40.9%).[2,9,14–17] In our study, prophylactic transcondylar screw placement had no complications. In the current literature, the complication rate for prophylactic screw placement ranges from 15 to 69% with the most common being seroma and infection.[17,18] Fluoroscopically guided transcondylar screw placement has been reported to have a 45% rate of complications, with 15% requiring revision surgery.[28] Despite all the published data, it is difficult to compare studies because different criteria for complication classification have been used, and the surgical techniques are not standardized.

Although our long-term outcome results were similar to recent studies where excellent outcome was reported in between 49.6 and 87% of dogs with HCF,[2,7,15,18,19] the strength of evidence provided by our long-term outcome results is limited for several reasons. First, radiographs were not taken after the first scheduled revisit appointment to avoid the risks of sedation in French Bulldogs and to avoid the cost of repeating radiographs in patients that were doing clinically well. Second, the patients did not have repeated clinical examinations—the long-term outcome was determined by a nonvalidated owner questionnaire created by the authors. To the authors' knowledge, validated questionnaires are only available for osteoarthritis and therefore would not elucidate information pertinent to this study. Finally, the questionnaire was only completed by 27 of 89 owners, which is a low response rate.

In this study, no association has been found between the type of surgical fixation and complications, although this may represent a type 2 error due to low numbers, as most complications occurred in dogs where a Kirschner wire was used, similar to previous reports.[2,15,18] Dogs that did not suffer complications were more likely to have an excellent or a good outcome.

This study has several limitations. It is a retrospective study, which may have caused selection bias. Not all contralateral elbows were evaluated with a CT scan, which is the preferred diagnostic modality.[13] Long-term outcome was based on a nonvalidated owner questionnaire, which makes comparisons with other studies challenging. Finally, the rate of response to the owner questionnaire was low (30.33%), but this is in line with other studies evaluating long-term outcome.[2]

Conclusion

In conclusion, 40% of French Bulldogs with HCF were diagnosed with a contralateral HIF. The presence of HIF could be one of the reasons French Bulldogs have a high prevalence of HCF. We would highly recommend CT imaging of both elbows prior to fracture repair and considering the placement of a prophylactic transcondylar screw if HIF is identified.

Note

The draft of this study was presented as an abstract at the BVOA conference in March 2022.

Authors' Contribution

P.L. contributed to the study design, acquisition of data, and data analysis and interpretation, and drafted and approved the manuscript. L.A. contributed to conception of the study, study design, acquisition of data, and data analysis and interpretation, and drafted and approved the manuscript. L.R. contributed to acquisition of data and data analysis and interpretation, and drafted and approved the manuscript. W.M. contributed to data analysis and interpretation and drafted and approved the manuscript. D.A. contributed to conception of the study, study design, acquisition of data, and data analysis and interpretation, and drafted and approved the manuscript.

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IVC Evidensia will pay for Open access.

Conflict of Interest

None declared.

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